

Dynamic Data-Driven Event Reconstruction for Atmospheric Releases

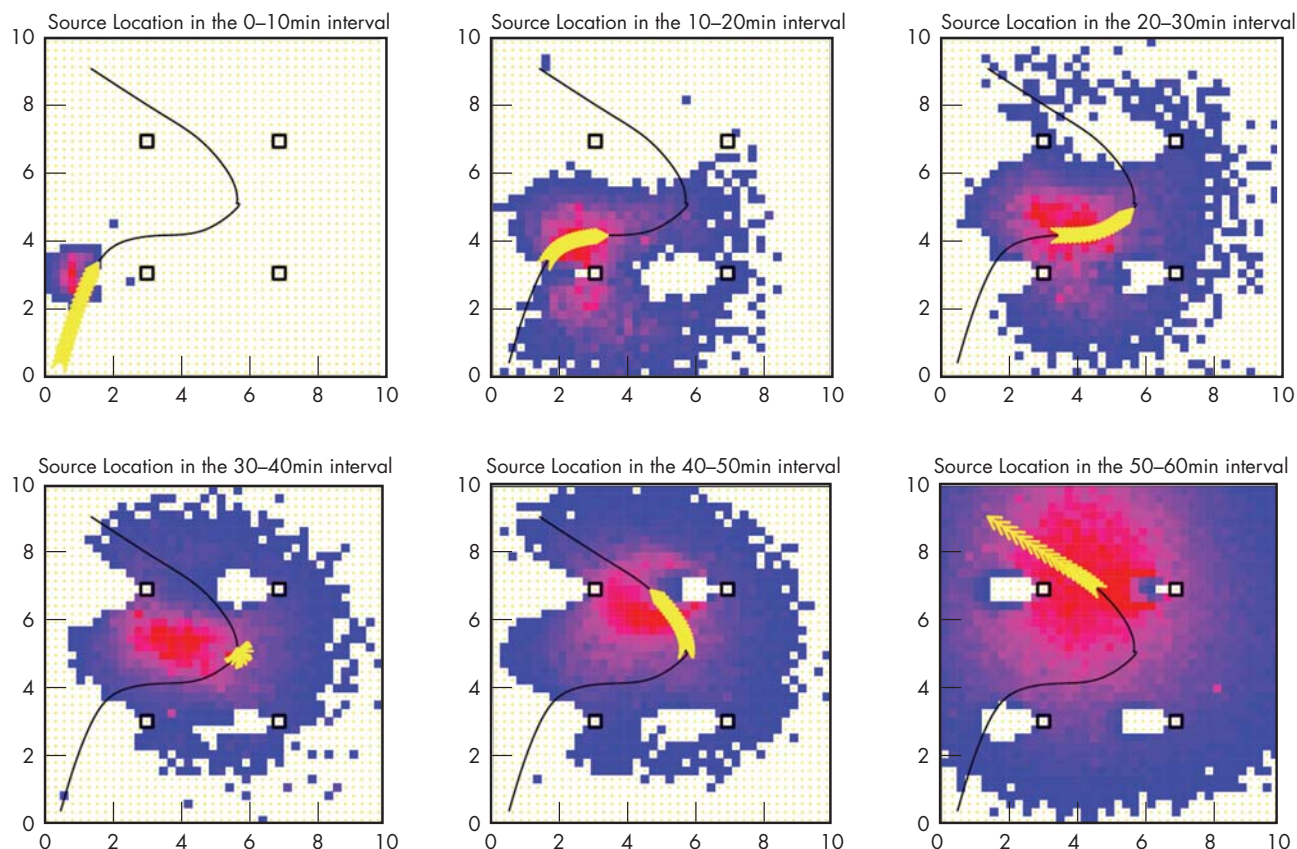


For more information contact **Gayle Sugiyama**
(925) 422-7266, sugiyama1@llnl.gov

For atmospheric releases, event reconstruction answers the critical questions – *How much material was released? When? Where? and What are the potential consequences?* Inaccurate estimation of the source term can lead to gross errors, time delays during a crisis, and even fatalities. We are developing a capability that seamlessly integrates observational data streams with predictive models to provide the best possible estimates of unknown source term

parameters, as well as optimal and timely situation analyses, consistent with both models and data.

Our approach uses Bayesian inference and stochastic sampling methods (Markov Chain and Sequential Monte Carlo) to reformulate the inverse problem into a solution based on efficient sampling of an ensemble of predictive simulations, guided by statistical comparisons with data.



Example of event reconstruction for a release from a moving source. Color panels represent time evolution of probability distribution of the source location. Red represents high probability of source location, and yellow arrows represent the actual source location.

Project Goals

We are developing a flexible and adaptable data-driven event-reconstruction capability for atmospheric releases that provides quantitative probabilistic estimates of the principal source-term parameters, such as the time-varying release rate and location; predictions of increasing fidelity as an event progresses and additional data become available; and analysis tools for sensor network design and uncertainty studies. Our computational framework incorporates multiple stochastic algorithms, operates with a range and variety of atmospheric models, and runs on multiple computer platforms, from workstations to large-scale computing resources. Our final goal is a multi-resolution capability for both real-time operational response and high-fidelity multi-scale applications.

Relevance to LLNL Mission

This project directly contributes to the Laboratory's homeland and national security missions by addressing a critical need for atmospheric release event-reconstruction tools. It will support the rapidly growing number of operational detection, warning, and incident characterization systems being developed and deployed by the Department of Homeland Security (such as BioWatch, BWIC system, national BioSurveillance Initiative) and the Department of Energy (such as the Biological Warning and Incident Characterization System, chemical sensor networks, and the Department of Energy Nuclear Incident Response Team assets and deployments). The event-reconstruction and sensor-siting tools developed by this project are targeted for integration into the next-generation National Atmospheric Release Advisory Center (NARAC) and DHS's new Interagency Modeling and Atmospheric Analysis Center, based at LLNL.

FY2004 Accomplishments and Results

In FY2004, we: 1) implemented a 2-D prototype Bayesian Markov Chain Monte Carlo (MCMC) atmospheric event-reconstruction capability and tested it against a variety of scenarios and synthetic data; 2) developed a MCMC capability using the NARAC 3D Lagrangian particle dispersion code LODI, and tested it against field experiment data; 3) developed a Sequential Monte Carlo (SMC) methodology for time-dependent problems and tested it using synthetic data; 4) investigated optimization methods for determining proposal distributions and improving convergence; 5) evaluated the relative performance of MCMC and SMC methods using synthetic data; 6) designed a MCMC and SMC computational framework on massively parallel platforms; and 7) demonstrated the effectiveness of the SMC methodology for detecting moving sources using synthetic data.

Related References

1. Kosovic, B., G. Sugiyama, K. Dyer, W. Hanley, G. Johannesson, S. Larsen, G. Loosmore, J. K. Lundquist, A. Mirin, J. Nitao, and R. Serban, "Dynamic Data-Driven Event Reconstruction for Atmospheric Releases," *Second Sandia Workshop on Large-Scale PDE-Constrained Optimization*, Santa Fe, New Mexico, May 19-21, 2004.
2. Kosovic, B., G. Sugiyama, K. Dyer, W. Hanley, G. Johannesson, S. Larsen, G. Loosmore, J. K. Lundquist, A. Mirin, J. Nitao, and R. Serban, "Dynamic Data-Driven Event Reconstruction for Atmospheric Releases," *Eighth Annual George Mason University Transport and Dispersion Modeling Conference*, Fairfax, Virginia, July 13-15, 2004.
3. Sugiyama, G., K. Dyer, W. Hanley, G. Johannesson, B. Kosovic, S. Larsen, G. Loosmore, J. K. Lundquist, A. Mirin, J. Nitao, and R. Serban, "Markov-Chain Monte-Carlo and Sequential Monte-Carlo Approaches to Dynamic Data-Driven Event Reconstruction for Atmospheric Releases," *Second Workshop on Monte Carlo Methods*, Boston, Massachusetts, August 27-28, 2004.

FY2005 Proposed Work

Next year, we will: 1) implement a SMC atmospheric event-reconstruction capability based on NARAC operational models; 2) develop procedures and tools for input and model error quantification necessary for the event-reconstruction framework; 3) extend the event-reconstruction capability to handle complex terrain and an extended range of potential release types; 4) develop a multi-resolution capability for problems requiring multiple levels of models to accurately characterize the release event; 5) continue developing and testing efficient stochastic sampling and convergence algorithms; 6) explore methods for incorporating alternative input data types; and 7) enhance performance on massively parallel platforms for efficient event-reconstruction of complex atmospheric releases.